

WHAT IS CLAIMED IS:

- 1               1. A method for determining aperture phase distributions for use in  
2 radiating signals with an active phased array antenna having a plurality of shaped beams and  
3 a plurality of carriers, the method comprising:
  - 4               allocating distinct initial aperture phase distributions corresponding to the  
5 plurality of carriers; and
  - 6               optimizing the aperture phase distributions to simultaneously increase carrier-  
7 signal power and reduce an intermodulation product radiated in the respective coverage areas  
8 in accordance with amplification and radiation of signals having the modified aperture phase  
9 distributions.
- 1               2. The method recited in claim 1 further comprising modifying the initial  
2 aperture phase distributions for each of the plurality of carriers to generate respective  
3 radiation patterns that substantially correspond to respective coverage areas in accordance  
4 with amplification and radiation of signals having the initial aperture phase distributions.
- 1               3. The method recited in claim 1 wherein the respective coverage areas  
2 for the plurality of carriers are substantially the same.
- 1               4. The method recited in claim 1 wherein at least one of the initial  
2 aperture phase distributions is substantially paraboloidal.
- 1               5. The method recited in claim 1 wherein at least one of the initial  
2 aperture phase distributions is substantially hyperbolically paraboloidal.
- 1               6. The method recited in claim 1 wherein a first of the initial aperture  
2 phase distributions has two or more orthogonal planes of symmetry about an axis orthogonal  
3 to an aperture plane and a second of the initial aperture phase distributions is asymmetric  
4 about the axis.
- 1               7. The method recited in claim 1 wherein a second of the initial aperture  
2 phase distributions is substantially related to a first of the initial aperture phase distributions  
3 by complex conjugation and 180° rotation of underlying complex aperture voltage  
4 distributions.

1                   8.     The method recited in claim 1 wherein the intermodulation product  
2     comprises a third-order intermodulation product.

1                   9.     The method recited in claim 1 wherein the intermodulation product  
2     comprises a fifth-order intermodulation product.

1                   10.    The method recited in claim 1 wherein the intermodulation product  
2     comprises an in-band intermodulation product.

1                   11.    The method recited in claim 1 wherein the active phased array antenna  
2     further comprises a second plurality of carriers, the method further comprising:

3                         allocating second initial aperture phase distributions corresponding to the  
4     second plurality of carriers, each such second initial aperture phase distribution being  
5     substantially equal to one of the initial aperture phase distributions;

6                         modifying the second initial aperture phase distributions for each of the  
7     second plurality of carriers to generate respective radiation patterns that substantially  
8     correspond to respective coverage areas in accordance with amplification and radiation of  
9     signals having the second initial aperture phase distributions; and

10                         optimizing the modified second aperture phase distributions to simultaneously  
11     increase carrier-signal power and reduce an intermodulation product radiated in the  
12     respective coverage areas in accordance with amplification and radiation of signals with the  
13     modified aperture phase distributions and second modified aperture phase distributions.

1                   12.    The method recited in claim 11 wherein each of the plurality of carriers  
2     and the second plurality of carriers is less than five in number.

1                   13.    A method for radiating a plurality of shaped beams with an active  
2     phased array antenna having a plurality of carriers, wherein the beams have aperture phase  
3     distributions determined with the method recited in claim 1.

1                   14.    A method for radiating a plurality of shaped beams with an active  
2     phased array antenna having a plurality of carriers, the method comprising:  
3                         radiating a first of the plurality of shaped beams with a first of the plurality of  
4     carriers; and

5 radiating a second of the plurality of shaped beams with a second of the  
6 plurality of carriers,

7 wherein the plurality of shaped beams have aperture phase distributions  
8 determined in accordance with the following:

allocating distinct initial aperture phase distributions corresponding to  
the plurality of carriers;

11 modifying the initial aperture phase distributions for each of the  
12 plurality of carriers to generate respective radiation patterns that substantially correspond to  
13 respective coverage areas in accordance with amplification and radiation of signals having  
14 the initial aperture phase distributions; and

15 optimizing the modified aperture phase distributions to simultaneously  
16 increase carrier-signal power and reduce an intermodulation product radiated in the  
17 respective coverage areas in accordance with amplification and radiation of signals having  
18 the modified aperture phase distributions.

1                   15. The method recited in claim 14 wherein the respective coverage areas  
2 for the plurality of carriers are substantially the same.

1                   16. The method recited in claim 14 wherein at least one of the initial  
2 aperture phase distributions is substantially paraboloidal.

1                   17. The method recited in claim 14 wherein at least one of the initial  
2 aperture phase distributions is substantially hyperbolically paraboloidal.

1                   18. The method recited in claim 14 wherein a first of the initial aperture  
2 phase distributions is rotationally symmetric about an axis orthogonal to an aperture plane  
3 and a second of the initial aperture phase distributions is asymmetric about an axis orthogonal  
4 to the aperture plane.

1                   19. The method recited in claim 14 wherein a second of the initial aperture  
2 phase distributions is substantially related to a first of the initial aperture phase distributions  
3 by complex conjugation and 180° rotation of underlying complex aperture voltage  
4 distributions.

1                   20. The method recited in claim 14 wherein the intermodulation product  
2 comprises a third-order intermodulation product.

1                   21. The method recited in claim 14 wherein the intermodulation product  
2 comprises a fifth-order intermodulation product.

1                   22. The method recited in claim 14 wherein the intermodulation product  
2 comprises an in-band intermodulation product.

1                   23. The method recited in claim 14 wherein the active phased array  
2 antenna further comprises a second plurality of carriers, the method further comprising:  
3                   radiating a third of the plurality of shaped beams with a first of the second  
4 plurality of carriers;  
5                   radiating a fourth of the plurality of shaped beams with a second of the second  
6 plurality of carriers,

7                   wherein the plurality of shaped beams have aperture phase distributions  
8 further determined in accordance with the following:

9                   allocating second initial aperture phase distributions corresponding to  
10 the second plurality of carriers, each such second initial aperture phase distribution being  
11 substantially equal to one of the initial aperture phase distributions;

12                  modifying the second initial aperture phase distributions for each of the  
13 second plurality of carriers to generate respective radiation patterns that substantially  
14 correspond to respective coverage areas in accordance with amplification and radiation of  
15 signals having the second initial aperture phase distributions; and

16                  optimizing the modified second aperture phase distributions to  
17 simultaneously increase carrier-signal power and reduce an intermodulation product radiated  
18 in the respective coverage areas in accordance with amplification and radiation of signals  
19 with the modified aperture phase distributions and second modified aperture phase  
20 distributions.

1                   24. The method recited in claim 23 wherein each of the plurality of carriers  
2 and the second plurality of carriers is less than five in number.

1                   25. An active phased array antenna comprising:  
2                   a plurality of antenna elements;  
3                   a plurality of filter elements coupled with the antenna elements;  
4                   a plurality of amplifier elements coupled with the filter elements;  
5                   a plurality of beam ports; and

6                   a beamformer having a plurality of elemental paths for coupling the beam  
7 ports with the amplifier elements, wherein the beamformer includes phase shifters adapted to  
8 provide aperture phase distributions per beam to the amplifier elements in accordance with  
9 the following:

10                   allocating distinct initial aperture phase distributions corresponding to  
11 the plurality of amplifier elements; and

12                   optimizing the aperture phase distributions to simultaneously increase  
13 carrier-signal power and reduce an intermodulation product radiated in the respective  
14 coverage areas in accordance with amplification and radiation of signals having the modified  
15 aperture phase distributions with the amplifier elements and antenna elements.

1                   26.       The active phased array antenna recited in claim 25 wherein the  
2 beamformer is further adapted to modify the initial aperture phase distributions for each of  
3 the plurality of amplifier elements to generate respective radiation patterns that substantially  
4 correspond to respective coverage areas in accordance with amplification and radiation of  
5 signals having the initial aperture phase distributions with the amplifier elements and antenna  
6 elements.

1                   27.       The active phased array antenna recited in claim 25 wherein the  
2 respective coverage areas for the plurality of carriers are substantially the same.

1                   28.       The active phased array antenna recited in claim 25 wherein at least  
2 one of the initial aperture phase distributions is substantially paraboloidal.

1                   29.       The active phased array antenna recited in claim 25 wherein at least  
2 one of the initial aperture phase distributions is substantially hyperbolically paraboloidal.

1                   30.       The active phased array antenna recited in claim 25 wherein a first of  
2 the initial aperture phase distributions is rotationally symmetric about an axis orthogonal to  
3 an aperture plane and a second of the initial aperture phase distributions is asymmetric about  
4 an axis orthogonal to the aperture plane.

1                   31.       The active phased array antenna recited in claim 25 wherein a second  
2 of the initial aperture phase distributions is substantially related to a first of the initial  
3 aperture phase distributions by complex conjugation and 180° rotation of underlying complex  
4 aperture voltage distributions.

1                   32. The active phased array antenna recited in claim 25 wherein the  
2 intermodulation product comprises a third-order intermodulation product.

1                   33. The active phased array antenna recited in claim 25 wherein the  
2 intermodulation product comprises a fifth-order intermodulation product.

1                   34. The active phased array antenna recited in claim 25 wherein the  
2 intermodulation product comprises an in-band intermodulation product.

1                   35. The active phased array antenna recited in claim 25 wherein the phase  
2 shifters are further adapted to provide aperture phase distributions to the amplifier elements  
3 in accordance with the following:

4                   allocating second initial aperture phase distributions corresponding to the  
5 second plurality of amplifier elements, each such second initial aperture phase distribution  
6 being substantially equal to one of the initial aperture phase distributions;

7                   modifying the second initial aperture phase distributions for each of the  
8 second plurality of amplifier elements to generate respective radiation patterns that  
9 substantially correspond to respective coverage areas in accordance with amplification and  
10 radiation of signals having the second initial aperture phase distributions with the amplifier  
11 elements and antenna elements; and

12                  optimizing the modified second aperture phase distributions to simultaneously  
13 increase carrier-signal power and reduce an intermodulation product radiated in the  
14 respective coverage areas in accordance with amplification and radiation of signals having  
15 the modified aperture phase distributions and second modified aperture phase distributions  
16 with the amplifier elements and antenna elements.